

§ 86.144–94

40 CFR Ch. I (7–1–14 Edition)

$$M_{\text{CH}_3\text{OH}} = \rho_{\text{CH}_3\text{OH}} V_{\text{mix}} \times (C_{\text{CH}_3\text{OH}, \text{rl}} - C_{\text{CH}_3\text{OH}, \text{d}})$$

Where,

- (A)  $M_{\text{CH}_3\text{OH}}$  = methanol mass change,  $\mu\text{g}$ .
- (B)  $\rho_{\text{CH}_3\text{OH}} = 37.71 \text{ g/ft}^3$ , density of pure vapor at 68 °F.
- (C)  $V_{\text{mix}}$  = total dilute sample volume, in  $\text{ft}^3$ , calculated as appropriate for the collection technique used.
- (D)  $C_{\text{CH}_3\text{OH}, \text{rl}}$  = methanol concentration of diluted running loss sample, in ppm carbon equivalent.
- (E)  $C_{\text{CH}_3\text{OH}, \text{d}}$  = methanol concentration of dilution air, in ppm carbon equivalent.

(ii) Hydrocarbon emissions:

$$M_{\text{HC}} = \rho_{\text{HC}} V_{\text{mix}} 10^{-6} (C_{\text{HC}, \text{rl}} - C_{\text{HC}, \text{d}})$$

Where,

- (A)  $M_{\text{HC}}$  = hydrocarbon mass change, g.

- (B)  $\rho_{\text{HC}} = 16.88 \text{ g/ft}^3$ , density of pure vapor at 68 °F (for hydrogen to carbon ratio of 2.3).

- (C)  $V_{\text{mix}}$  = total dilute sample volume, in  $\text{ft}^3$ , calculated as appropriate for the collection technique used.

- (D)  $C_{\text{HC}, \text{rl}}$  = hydrocarbon concentration of diluted running loss sample, in ppm carbon equivalent.

- (E)  $C_{\text{HC}, \text{d}}$  = hydrocarbon concentration of dilution air, in ppm carbon equivalent.

(c) If the test fuel contains at least 25% oxygenated compounds by volume, measure the concentration of oxygenated compounds directly using a photoacoustic analyzer specified in 40 CFR 1065.269 or using impingers as described in 40 CFR 1065.805(f). Calculate total hydrocarbon equivalent emissions with the following equation, using density values specified in 40 CFR 1066.1005(f):

$$m_{\text{THCE}} = m_{\text{THC}} + \rho_{\text{THC}} \cdot \sum_{i=1}^N \frac{m_{\text{OHCi}}}{\rho_{\text{OHCi}}} \cdot (1 - RF_{\text{OHCi}[\text{THC-FID}]})$$

Where:

$m_{\text{THCE}}$  = the sum of the mass of THCE in the SHED.

$m_{\text{THC}}$  = the mass of THC and all oxygenated hydrocarbons in the SHED, as measured by the FID. Calculate THC mass based on  $\rho_{\text{THC}}$ .

$\rho_{\text{THC}}$  = the effective  $\text{C}_1$ -equivalent density of THC as specified in 40 CFR 1066.1005(f).

$m_{\text{OHCi}}$  = the mass of oxygenated species  $i$  in the SHED.

$\rho_{\text{OHCi}}$  = the  $\text{C}_1$ -equivalent density of oxygenated species  $i$ .

$RF_{\text{OHCi}[\text{THC-FID}]}$  = the response factor of a THC-FID to oxygenated species  $i$  relative to propane on a  $\text{C}_1$ -equivalent basis as determined in 40 CFR 1065.845.

(d)(1) For the full three-diurnal test sequence, there are two final results to report:

(i) The sum of the adjusted total mass emissions for the diurnal and hot soak tests ( $M_{\text{DI}} + M_{\text{HS}}$ ); and

(ii) The adjusted total mass emissions for the running loss test, on a

grams per mile basis= $M_{\text{RL}}/D_{\text{RL}}$ , where  $D_{\text{RL}}$  = miles driven for the running loss test (see § 86.134–96(c)(6)).

(2) For the supplemental two-diurnal test sequence, there is one final result to report: the sum of the adjusted total mass emissions for the diurnal and hot soak tests ( $M_{\text{DI}} + M_{\text{HS}}$ ), described in §§ 86.133–96(p) and 86.138–96(k), respectively.

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§ 86.144–94 Calculations; exhaust emissions.

The final reported test results shall be computed by use of the following formula:

(a) For light-duty vehicles and light duty trucks:

$$Y_{\text{wm}} = 0.43 \left( \frac{(Y_{\text{ct}} + Y_{\text{s}})}{(D_{\text{ct}} + D_{\text{s}})} \right) + 0.57 \left( \frac{(Y_{\text{ht}} + Y_{\text{s}})}{(D_{\text{ht}} + D_{\text{s}})} \right)$$

Where:

(1)  $Y_{WM}$  = Weighted mass emissions of each pollutant, i.e., THC, CO, THCE, NMHC, NMHCE,  $CH_4$ ,  $NO_X$ , or  $CO_2$ , in grams per vehicle mile.

(2)  $Y_{ct}$  = Mass emissions as calculated from the "transient" phase of the cold start test, in grams per test phase.

(3)  $Y_{ht}$  = Mass emissions as calculated from the "transient" phase of the hot start test, in grams per test phase.

(4)  $Y_s$  = Mass emissions as calculated from the "stabilized" phase of the cold start test, in grams per test phase.

(5)  $D_{ct}$  = The measured driving distance from the "transient" phase of the cold start test, in miles.

(6)  $D_{ht}$  = The measured distance from the "transient" phase of the hot start test, in miles.

(7)  $D_s$  = The measured driving distance from the "stabilized" phase of the cold start test, in miles.

(b) The mass of each pollutant for each phase of both the cold start test and the hot start test is determined from the following:

(1) Total hydrocarbon mass:

$$HC_{mass} = V_{mix} \times \text{Density}_{HC} \times (HC_{conc}/1,000,000)$$

(2) Oxides of nitrogen mass:

$$NOx_{mass} = V_{mix} \times \text{Density}_{NO_2} \times K_H \times (NOx_{conc}/1,000,000)$$

(3) Carbon monoxide mass:

$$CO_{mass} = V_{mix} \times \text{Density}_{CO} \times (CO_{conc}/1,000,000)$$

(4) Carbon dioxide mass:

$$CO_{2mass} = V_{mix} \times \text{Density}_{CO_2} \times (CO_{2conc}/100)$$

(5) Methanol mass:

$$CH_3OH_{mass} = V_{mix} \times \text{Density}_{CH_3OH} \times (CH_3OH_{conc}/1,000,000)$$

(6) Formaldehyde mass:

$$HCHO_{mass} = V_{mix} \times \text{Density}_{HCHO} \times (HCHO_{conc}/1,000,000)$$

(7) Total hydrocarbon equivalent mass:

$$THCE_{mass} = HC_{mass} + 13.8756/32.042 \times (CH_3OH_{mass}) + 13.8756/32.0262 \times (HCHO_{mass})$$

(8) Non-methane hydrocarbon mass:

$$NMHC_{mass} = V_{mix} \times \text{Density}_{NMHC} \times (NMHC_{conc}/1,000,000)$$

(9) Non-methane hydrocarbon equivalent mass:

$$NMHCE_{mass} = NMHC_{mass} + 13.8756/32.042 \times (CH_3OH_{mass}) + 13.8756/32.0262 \times (HCHO_{mass})$$

(10) Methane mass:

$$CH_{4mass} = V_{mix} \times \text{Density}_{CH_4} = (CH_{4conc}/1,000,000)$$

(11) Nitrous Oxide Mass:

$$V_{mix} \times \text{Density}_{N_2O} \times (N_2O_{conc}/1,000,000)$$

(c) Meaning of symbols:

(1)(i)  $HC_{mass}$  = Total hydrocarbon emissions, in grams per test phase.

(ii)  $Density_{HC}$  = Density of total hydrocarbon.

(A) For gasoline-fuel, diesel-fuel and methanol fuel;  $Density_{HC}$  = 16.33 g/ft<sup>3</sup>-carbon atom (0.5768 kg/m<sup>3</sup>-carbon atom), assuming an average carbon to hydrogen ratio of 1:1.85, at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(B) For natural gas and liquefied petroleum gas-fuel;  $Density_{HC}$  = 1.1771 (12.011+H/C (1.008)) g/ft<sup>3</sup>-carbon atom (0.04157(12.011+H/C (1.008))kg/m<sup>3</sup>-carbon atom), where H/C is the hydrogen to carbon ratio of the hydrocarbon components of the test fuel, at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $HC_{conc}$  = Total hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent, i.e., equivalent propane  $\times 3$ .

(B)  $HC_{conc} = HC_e - HC_d(1 - 1/DF)$ .

Where:

(iv)(A)  $HC_e$  = Total hydrocarbon concentration of the dilute exhaust sample or, for diesel-cycle (or methanol-fueled vehicles, if selected), average hydrocarbon concentration of the dilute exhaust sample as calculated from the integrated THC traces, in ppm carbon equivalent.

(B)  $HC_e = FID\ HC_e - (r)C_{CH_3OHe}$ .

(v)  $FID\ HC_e$  = Concentration of total hydrocarbon plus methanol in dilute exhaust as measured by the FID, ppm carbon equivalent.

(vi)  $r$  = FID response to methanol.

(vii)  $C_{CH_3OHe}$  = Concentration of methanol in dilute exhaust as determined from the dilute exhaust methanol sample in ppm carbon. For vehicles not fueled with methanol,  $C_{CH_3OHe}$  equals zero.

(viii)(A)  $HC_d$  = Total hydrocarbon concentration of the dilution air as measured, in ppm carbon equivalent.

(B)  $HC_d$  = FID  $HC_d - (r)C_{CH^3OHd}$ .

(ix) FID  $HC_d$  = Concentration of total hydrocarbon plus methanol in dilution air as measured by the FID, ppm carbon equivalent.

(x)  $C_{CH^3OHd}$  = Concentration of methanol in dilution air as determined from dilution air methanol sample in ppm carbon. For vehicles not fueled with methanol,  $C_{CH^3OHd}$  equals zero.

(2)(i)  $NOx_{mass}$  = Oxides of nitrogen emissions, in grams per test phase.

(ii)  $Density_{NO_2}$  = Density of oxides of nitrogen is 54.16 g/ft<sup>3</sup> (1.913 kg/m<sup>3</sup>) assuming they are in the form of nitrogen dioxide, at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $NOx_{conc}$  = Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, in ppm.

(B)  $NOx_{conc} = NOx_e - NOx_d(1 - (1/DF))$ .

Where:

(iv)  $NOx_e$  = Oxides of nitrogen concentration of the dilute exhaust sample as measured, in ppm.

(v)  $NOx_d$  = Oxides of nitrogen concentration of the dilution air as measured, in ppm.

(3)(i)  $CO_{mass}$  = Carbon monoxide emissions, in grams per test phase.

(ii)  $Density_{CO}$  = Density of carbon monoxide is 32.97 g/ft<sup>3</sup> (1.164 kg/m<sup>3</sup>), at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $CO_{conc}$  = Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapor, and  $CO_2$  extraction, in ppm.

(B)  $CO_{conc} = CO_e - CO_d(1 - (1/DF))$ .

Where:

(iv)(A)  $CO_e$  = Carbon monoxide concentration of the dilute exhaust volume corrected for water vapor and carbon dioxide extraction, in ppm.

(B)  $CO_e = (1 - 0.01925CO_{2e} - 0.000323R)CO_{em}$  for petroleum fuel with hydrogen to carbon ratio of 1.85:1.

(C)  $CO_e = [1 - (0.01 + 0.005HCR)CO_{2e} - 0.000323R]CO_{em}$  for methanol-fuel or natural gas-fuel or liquefied petroleum gas-fuel, where HCR is hydrogen-

to-carbon ratio as measured for the fuel used.

(v)  $CO_{em}$  = Carbon monoxide concentration of the dilute exhaust sample as measured, in ppm.

(vi)  $CO_{2e}$  = Carbon dioxide concentration of the dilute exhaust sample, in percent.

(vii) R = Relative humidity of the dilution air, in percent (see § 86.142(n)).

(viii)(A)  $CO_d$  = Carbon monoxide concentration of the dilution air corrected for water vapor extraction, in ppm.

(B)  $CO_d = (1 - 0.000323R)CO_{dm}$ .

Where:

(ix)  $CO_{dm}$  = Carbon monoxide concentration of the dilution air sample as measured, in ppm.

NOTE: If a CO instrument which meets the criteria specified in § 86.111 is used and the conditioning column has been deleted,  $CO_{em}$  must be substituted directly for  $CO_e$  and  $CO_{dm}$  must be substituted directly for  $CO_d$ .

(4)(i)  $CO_{2mass}$  = Carbon dioxide emissions, in grams per test phase.

(ii)  $Density_{CO_2}$  = Density of carbon dioxide is 51.81 g/ft<sup>3</sup> (1.830 kg/m<sup>3</sup>), at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $CO_{2conc}$  = Carbon dioxide concentration of the dilute exhaust sample corrected for background, in percent.

(B)  $CO_{2conc} = CO_{2e} - CO_{2d}(1 - (1/DF))$ .

Where:

(iv)  $CO_{2d}$  = Carbon dioxide concentration of the dilution air as measured, in percent.

(5)(i)  $CH_3OH_{mass}$  = Methanol emissions corrected for background, in grams per test phase.

(ii)  $Density_{CH_3OH}$  = Density of methanol is 37.71 g/ft<sup>3</sup>-carbon atom (1.332 kg/m<sup>3</sup>-carbon atom), at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $CH_3OH_{conc}$  = Methanol concentration of the dilute exhaust corrected for background, ppm.

(B)  $CH_3OH_{conc} = C_{CH_3OHe} - C_{CH_3OHd}(1 - (1/DF))$ .

Where:

(iv)(A)  $C_{CH_3OHe}$  = Methanol concentration in the dilute exhaust, ppm.

(B)

$$C_{\text{CH}_3\text{OH}_e} = \frac{3.813 \times 10^{-2} \times T_{\text{EM}} [(C_{\text{S1}} \times AV_{\text{S1}}) + (C_{\text{S2}} \times AV_{\text{S2}})]}{P_{\text{B}} \times V_{\text{EM}}}$$

(v)(A)  $C_{\text{CH}_3\text{OH}_d}$  = Methanol concentration in the dilution air, ppm. (B)

$$C_{\text{CH}_3\text{OH}_d} = \frac{3.813 \times 10^{-2} \times T_{\text{DM}} [(C_{\text{D1}} \times AV_{\text{D1}}) + (C_{\text{D2}} \times AV_{\text{D2}})]}{P_{\text{B}} \times V_{\text{DM}}}$$

(vi)  $T_{\text{EM}}$  = Temperature of methanol sample withdrawn from dilute exhaust, °R.

(vii)  $T_{\text{DM}}$  = Temperature of methanol sample withdrawn from dilution air, °R.

(viii)  $P_{\text{B}}$  = Barometric pressure during test, mm Hg.

(ix)  $V_{\text{EM}}$  = Volume of methanol sample withdrawn from dilute exhaust, ft<sup>3</sup>.

(x)  $V_{\text{DM}}$  = Volume of methanol sample withdrawn from dilution air, ft<sup>3</sup>.

(xi)  $C_{\text{S}}$  = GC concentration of sample drawn from dilute exhaust, µg/ml.

(xii)  $C_{\text{D}}$  = GC concentration of sample drawn from dilution air, µg/ml.

(xiii)  $AV_{\text{S}}$  = Volume of absorbing reagent (deionized water) in impinger through which methanol sample from dilute exhaust is drawn, ml.

(xiv)  $AV_{\text{D}}$  = Volume of absorbing reagent (deionized water) in impinger through which methanol sample from dilution air is drawn, ml.

(xv) 1 = first impinger.

(xvi) 2 = second impinger.

(xvii) 1 = first impinger.

(xviii) 2 = second impinger.

(6)(i)  $\text{HCHO}_{\text{mass}}$  = Formaldehyde emissions corrected for background, in grams per test phase.

(ii)  $\text{Density}_{\text{HCHO}}$  = Density of formaldehyde is 35.36 g/ft<sup>3</sup>- carbon atom (1.249 kg/m<sup>3</sup>-carbon atom), at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A)  $\text{HCHO}_{\text{conc}}$  = Formaldehyde concentration of the dilute exhaust corrected for background, in ppm.

(B)  $\text{HCHO}_{\text{conc}} = C_{\text{HCHO}_e} - C_{\text{HCHO}_d} (1 - (1/DF))$ .

Where:

(iv)(A)  $C_{\text{HCHO}_e}$  = Formaldehyde concentration in dilute exhaust, in ppm.

(B)

$$C_{\text{HCHO}_e} = \frac{4.069 \times 10^{-2} \times C_{\text{FDE}} \times V_{\text{AE}} \times Q \times T_{\text{EF}}}{V_{\text{SE}} \times P_{\text{B}}}$$

(v)(A)  $C_{\text{HCHO}_d}$  = Formaldehyde concentration in dilution air in ppm.

(B)

$$C_{\text{HCHO}_d} = \frac{4.069 \times 10^{-2} \times C_{\text{FDA}} \times V_{\text{AA}} \times Q \times T_{\text{DF}}}{V_{\text{SA}} \times P_{\text{B}}}$$

(vi)  $C_{\text{FDE}}$  = Concentration of DNPH derivative of formaldehyde from dilute exhaust sample in sampling solution, µg/ml.

(vii)  $V_{\text{AE}}$  = Volume of sampling solution for dilute exhaust formaldehyde sample, ml.

(viii)(A)  $Q$  = Ratio of molecular weights of formaldehyde to its DNPH derivative.

(B)  $Q = 0.1429$ .

(ix)  $T_{\text{EF}}$  = Temperature of formaldehyde sample withdrawn from dilute exhaust, °R.

(x)  $V_{\text{SE}}$  = Volume of formaldehyde sample withdrawn from dilute exhaust, ft<sup>3</sup>.

(xi)  $P_{\text{B}}$  = Barometric pressure during test, mm Hg.

(xii)  $C_{\text{FDA}}$  = Concentration of DNPH derivative of formaldehyde from dilution air sample in sampling solution, µg/ml.

(xiii)  $V_{\text{AA}}$  = Volume of sampling solution for dilution air formaldehyde sample, ml.

(xiv)  $T_{\text{DF}}$  = Temperature of formaldehyde sample withdrawn from dilution air, °R.

(xv)  $V_{SA}$  = Volume of formaldehyde sample withdrawn from dilution air,  $\text{ft}^3$ .

(7)(i)  $DF = 13.4/[\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e) \cdot 10^{-4}]$  for petroleum-fueled vehicles.

(ii) For methanol-fueled vehicles, where fuel composition is  $\text{C}_x\text{H}_y\text{O}_z$  as measured, or calculated, for the fuel used:

$$DF = \frac{100 \cdot \left( \frac{X}{x + \frac{y}{2} + 3.76 \cdot \left( x + \frac{y}{4} - \frac{z}{2} \right)} \right)}{\text{CO}_{2e} + \left( \text{HC}_e + \text{CO}_e + \text{C}_{\text{CH}_3\text{OH}_e} + \text{C}_{\text{HCHO}_e} \right) \cdot 10^{-4}}$$

(iii)

$$DF = \frac{100 \times \frac{x}{x + y/2 + 3.76(x + y/4)}}{\text{CO}_{2e} + (\text{NMHC}_e + \text{CH}_{4e} + \text{CO}_e) \times 10^{-4}}$$

for natural gas-fueled or liquefied petroleum gas-fueled vehicles where fuel composition is  $\text{C}_x\text{H}_y$  as measured for the fuel used.

(iv)(A)  $K_H$  = Humidity correction factor.

(B)  $K_H = 1/[1 - 0.0047(H - 75)]$ .

(C) For SI units,  $K_H = 1/[1 - 0.0329(H \times 10^{-7})]$ .

Where:

(v)(A)  $H$  = Absolute humidity in grains (grams) of water per pound (kilogram) of dry air.

(B)  $H = [(43.478)R_a \times P_d]/[P_B - (P_d \times R_a/100)]$ .

(C) For SI units,  $H = [(6.211)R_a \times P_d]/[P_B \times (P_d \times R_a/100)]$ .

(vi)  $R_a$  = Relative humidity of the ambient air, percent.

(vii)  $P_d$  = Saturated vapor pressure, mm Hg (kPa) at the ambient dry bulb temperature.

(viii)  $P_B$  = Barometric pressure, mm Hg (kPa).

(ix)(A)  $V_{\text{mix}}$  = Total dilute exhaust volume in cubic feet per test phase corrected to standard conditions (528°R (293 °K) and 760 mm Hg (101.3 kPa)).

(B) For PDP-CVS,  $V_{\text{mix}}$  is:

$$V_{\text{mix}} = \frac{V_o \times N \times (P_B - P_4) \times 528}{760 \times T_p}$$

(C) For SI units,

$$V_{\text{mix}} = \frac{V_o \times N \times (P_B - P_4) \times 293}{101.3 \times T_p}$$

Where:

(x)  $V_o$  = Volume of gas pumped by the positive displacement pump, in cubic feet ( $\text{m}^3$ ) per revolution. This volume is dependent on the pressure differential across the positive displacement pump.

(xi)  $N$  = Number of revolutions of the positive displacement pump during the test phase while samples are being collected.

(xii)  $P_B$  = Barometric pressure, mm Hg (kPa).

(xiii)  $P_4$  = Pressure depression below atmospheric measured at the inlet to the positive displacement pump, in mm Hg (kPa) (during an idle mode).

(xiv)  $T_p$  = Average temperature of dilute exhaust entering positive displacement pump during test, °R(°K).

(8)(i)  $\text{NMHC}_{\text{conc}} = \text{HC}_{\text{conc}} - (r_{\text{CH}_4} \times \text{CH}_{4\text{conc}})$ .

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(ii) Density<sub>NMHC</sub> = The density of non-methane hydrocarbon.

(A) For gasoline-fuel and diesel-fuel; Density<sub>NMHC</sub> = 16.33 g/ft<sup>3</sup>-carbon atom (0.5768 kg/m<sup>3</sup>-carbon atom), assuming an average carbon to hydrogen ratio of 1:1.85 at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(B) For natural gas and liquefied petroleum gas fuel; Density<sub>NMHC</sub> = 1.1771(12.011+H/C(1.008))g/ft<sup>3</sup>-carbon atom (0.04157(12.011+H/C(1.008))kg/m<sup>3</sup>-carbon atom), where H/C is the hydrogen to carbon ratio of the non-methane hydrocarbon components of the test fuel, at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(iii)(A) CH<sub>4conc</sub> = Methane concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent.

(B) CH<sub>4conc</sub> = CH<sub>4e</sub> - CH<sub>4d</sub>(1 - 1/DF)

Where:

(iv) CH<sub>4e</sub> = Methane exhaust bag concentration in ppm carbon equivalent.

(v) CH<sub>4d</sub> = Methane concentration of the dilution air in ppm carbon equivalent.

(vi) rCH<sub>4</sub>=HC FID response to methane as measured in § 86.121(d).

(9)(i) CH<sub>4mass</sub> = Methane emissions, in grams per test phase.

(ii) Density<sub>CH<sub>4</sub></sub> = Density of methane is 18.89 g/ft<sup>3</sup>-carbon atom (0.6672 kg/m<sup>3</sup>-carbon atom), at 68 °F (20 °C) and 760 mm Hg (101.3 kPa) pressure.

(10)(i) N<sub>2Omass</sub> = Nitrous oxide emissions, in grams per test phase.

(ii) Density<sub>N<sub>2O</sub></sub> = Density of nitrous oxide is 51.81 g/ft<sup>3</sup> (1.83 kg/m<sup>3</sup>), at 68 °F (20 °C) and 760 mm Hg (101.3kPa) pressure.

(iii)(A) N<sub>2Oconc</sub> = Nitrous oxide concentration of the dilute exhaust sample corrected for background, in ppm.

(B) N<sub>2Oconc</sub> = N<sub>2Oe</sub> - N<sub>2Od</sub>(1 - (1/DF)).

Where:

N<sub>2Oe</sub> = Nitrous oxide concentration of the dilute exhaust sample as measured, in ppm.

N<sub>2Od</sub> = Nitrous oxide concentration of the dilution air as measured, in ppm.

(d) For petroleum-fueled vehicles, example calculation of mass values of exhaust emissions using positive displacement pump:

(1) For the "transient" phase of the cold start test assume the following: V<sub>o</sub> = 0.29344 ft<sup>3</sup>rev; N = 10,485; R = 48.0 pct;

R<sub>a</sub> = 48.2 percent; P<sub>B</sub> = 762 mm Hg; P<sub>d</sub> = 22.225 mm Hg; P<sub>4</sub> = 70 mm Hg; T<sub>p</sub> = 570 °R; HC<sub>e</sub> = 105.8 ppm, carbon equivalent; NO<sub>x</sub><sub>e</sub> = 11.2 ppm; CO<sub>em</sub> = 306.6 ppm; CO<sub>2e</sub> = 1.43 percent; CH<sub>4e</sub> = 10.74 ppm; HC<sub>d</sub> = 12.1 ppm; NO<sub>x</sub><sub>d</sub> = 0.8 ppm; CO<sub>dm</sub> = 15.3 ppm; CO<sub>2d</sub> = 0.032 percent; CH<sub>4d</sub> = 2.20 ppm; D<sub>ct</sub> = 3.598 miles.

Then:

(i) V<sub>mix</sub> = (0.29344)(10,485)(762-70)(528)/(760)(570) = 2595.0 ft<sup>3</sup> per test phase.

(ii) H = (43.478)(48.2)(22.225)/762 - (22.225)(48.2/100) = 62 grains of water per pound of dry air.

(iii) K<sub>H</sub> = 1/[1 - 0.0047(62-75)] = 0.9424.

(iv) CO<sub>e</sub> = [1-0.01925(1.43) - 0.000323(48)](306.6) = 293.4 ppm.

(v) CO<sub>d</sub> = [1 - 0.000323(48)](15.3) = 15.1 ppm.

(vi) DF = 13.4/[1.43+10<sup>-4</sup>(105.8+293.4)] = 9.116.

(vii) HC<sub>conc</sub> = 105.8-12.1(1 - 1/9.116) = 95.03 ppm.

(viii) HC<sub>mass</sub> = (2595)(16.33)(95.03/1,000,000) = 4.027 grams per test phase.

(ix) NO<sub>xconc</sub> = 11.2 - 0.8(1 - 1/9.116) = 10.49 ppm.

(x) NO<sub>xmass</sub> = (2595)(54.16)(10.49/1,000,000)(0.9424) = 1.389 grams per test phase.

(xi) CO<sub>conc</sub> = 293.4 - 15.1(1 - 1/9.116) = 280.0 ppm.

(xii) CO<sub>mass</sub> = (2595)(32.97)(280/1,000,000) = 23.96 grams per test phase.

(xiii) CO<sub>2conc</sub> = 1.43 - 0.032(1 - 1/9.116) = 1.402 percent.

(xiv) CO<sub>2mass</sub> = (2595.0)(51.85)(1.402/100) = 1886 grams per test phase.

(xv) CH<sub>4conc</sub> = 10.74 - 2.2 (1 - 1/9.116) = 8.78 ppm.

(xvi) NMHC<sub>conc</sub> = 95.03 - 8.78 = 86.25 ppm.

(xvii) NMHC<sub>mass</sub> = (2595)(16.33)(86.25)/1,000,000 = 3.655 grams per test phase.

(2) For the stabilized portion of the cold start test assume that similar calculations resulted in the following:

(i) HC<sub>mass</sub> = 0.62 gram per test phase.

(ii) NO<sub>xmass</sub> = 1.27 grams per test phase.

(iii) CO<sub>mass</sub> = 5.98 grams per test phase.

(iv) CO<sub>2mass</sub> = 2346 grams per test phase.

(v) D<sub>s</sub> = 3.902 miles.

(vi) NMHC<sub>mass</sub> = 0.50 gram per test phase.

(3) For the “transient” portion of the hot start test assume that similar calculations resulted in the following:

- (i)  $\text{HC}_{\text{mass}} = 0.51$  gram per test phase.
- (ii)  $\text{NOx}_{\text{mass}} = 1.38$  grams per test phase.
- (iii)  $\text{CO}_{\text{mass}} = 5.01$  grams per test phase.
- (iv)  $\text{CO}_{2\text{mass}} = 1758$  grams per test phase.
- (v)  $D_{\text{ht}} = 3.598$  miles.
- (vi)  $\text{NMHC}_{\text{mass}} = 0.44$  grams per test phase.

(4) Weighted mass emission results:

- (i)  $\text{HC}_{\text{wm}} = 0.43[(4.027+0.62)/(3.598+3.902)] + 0.57[(0.51+0.62)/(3.598+3.902)] = 0.352$  gram per vehicle mile.
- (ii)  $\text{NOx}_{\text{wm}} = 0.43[(1.389+1.27)/(3.598+3.902)] + 0.57[(1.38+1.27)/(3.598+3.902)] = 0.354$  gram per vehicle mile.
- (iii)  $\text{CO}_{\text{wm}} = 0.43[(23.96+5.98)/(3.598+3.902)] + 0.57[(5.01+5.98)/(3.598+3.902)] = 2.55$  grams per vehicle mile.
- (iv)  $\text{CO}_{2\text{wm}} = 0.43[(1886+2346)/(3.598+3.902)] + 0.57[(1758+2346)/(3.598+3.902)] = 555$  gram per vehicle mile.
- (v)  $\text{NMHC}_{\text{wm}} = 0.43[(3.655 + 0.50)/(3.598 + 3.902)] + 0.57[(0.44 + 0.50)/(3.598 + 3.902)] = 0.310$  gram per vehicle mile.

(e) For methanol-fueled vehicles with measured fuel composition of  $\text{CH}_{3.487}\text{O}_{0.763}$ , example calculation of exhaust emissions using positive displacement pump:

(1) For the “transient” phase of the cold start test assume the following:  $V_0 = 0.29344$  ft<sup>3</sup> rev;  $N=25,801$ ;  $R=37.5$  pct;  $R_a=37.5$  percent;  $P_B = 725.42$  mm Hg;  $P_d = 22.02$  mm Hg;  $P_4 = 70$  mm Hg;  $T_p = 570$  deg.R;  $\text{FID HC}_e = 14.65$  ppm, carbon equivalent;  $r=0.788$ ;  $T_{\text{EM}} = 527.67$  deg.R;  $V_{\text{EM}} = 0.2818$  ft<sup>3</sup>;  $C_{S1} = 7.101$ ;  $AV_{S1} = 15.0$  ml;  $C_{S2} = 0.256$ ;  $AV_{S2} = 15.0$  ml;  $T_{\text{DM}} = 527.67$  deg.R;  $V_{\text{DM}} = 1.1389$  ft<sup>3</sup>;  $C_{D1} = 0.439$ ;  $AV_{D1} = 15.0$  ml;  $C_{D2} = 0.0$ ;  $AV_{D2} = 15.0$  ml;  $C_{\text{FDE}} = 8.970$  µg/ml;  $V_{\text{AE}} = 5.0$  ml;  $Q=0.1429$ ;  $T_{\text{EF}} = 527.67$  deg.R;  $V_{\text{SE}} = 0.2857$  ft<sup>3</sup>;  $C_{\text{FDA}} = 0.39$  µg/ml;  $V_{\text{AA}} = 5.0$  ml;  $T_{\text{DF}} = 527.67$  deg.R;  $V_{\text{SA}} = 1.1043$  ft<sup>3</sup>;  $\text{NO}_x = 5.273$  ppm;  $\text{CO}_{\text{em}} = 98.8$  ppm;  $\text{CO}_{2e} = 0.469$  pct;  $\text{CH}_{4e} = 2.825$  ppm;  $\text{FID HC}_d = 2.771$  ppm;  $\text{NO}_x = 0.146$  ppm;  $\text{CO}_{\text{dm}} = 1.195$  ppm;  $\text{CO}_{2d} = 0.039$  percent;  $\text{CH}_{4d} = 2.019$  ppm;  $D_{\text{ct}}=3.583$  miles.

Then:

$$(i) V_{\text{mix}} = (0.29344)(25,801)(725.42 - 70)(528)/(760)(570) = 6048.1.0 \text{ ft}^3 \text{ per test phase.}$$

$$(ii) H = (43.478)(37.5)(22.02)/[725.42 - (22.02 \times 37.5/100)] = 50 \text{ grains of water per pound of dry air.}$$

$$(iii) K_H = 1/[1 - 0.0047(50 - 75)] = 0.8951.$$

$$(iv) \text{CO}_e = [1 - (0.01 + 0.005 \times 3.487 \times 0.469) - 0.000323(37.5)] \times 98.8 = 96.332 \text{ ppm.}$$

$$(v) \text{CO}_d = (1 - 0.000323(37.5)) \times 1.195 = 1.181 \text{ ppm.}$$

$$(vi) \text{C}_{\text{CH}_3\text{OH}_e} = (3.813 \times 10^{-2})(527.67)/[(7.101)(15.0) + (0.256)(15.0)]/(725.42)(0.2818) = 10.86 \text{ ppm.}$$

$$(vii) \text{HCE} = 14.65 - (0.788)(10.86) = 6.092.$$

$$(viii) \text{DF} = 100(1/[1 + (3.487/2) + 3.76(1 + (3.487/4) - (0.763/2))]/0.469 + (6.092 + 96.332 + 10.86 + 0.664)(10^{-4}) = 24.939.$$

$$(ix) \text{C}_{\text{CH}_3\text{OH}_d} = (3.813 \times 10^{-2})(527.67)/[(0.439)(15.0) + (0.0)(15.0)]/(725.42)(1.1389) = 0.16 \text{ ppm.}$$

$$(x) \text{CH}_3\text{OH}_{\text{conc}} = 10.86 - 0.16(1 - 1/24.939) = 10.71 \text{ ppm.}$$

$$(xi) \text{CH}_3\text{OH}_{\text{mass}} = 6048.1 \times 37.71 \times (10.71/1,000,000) = 2.44 \text{ grams per test phase.}$$

$$(xii) \text{HC}_{\text{conc}} = [14.65 - (0.788)(10.86)] - [2.771 - (0.788)(0.16)] (1 - 1/24.94) = 3.553 \text{ ppm.}$$

$$(xiii) \text{HC}_{\text{mass}} = (6048.1)(16.33)(3.553/1,000,000) = 0.35 \text{ grams per test phase.}$$

$$(xiv) \text{C}_{\text{HCHO}_e} = 4.069 \times 10^{-2}(8.970)(5.0)(0.1429)(527.67)/(0.2857)(725.42) = 0.664 \text{ ppm.}$$

$$(xv) \text{C}_{\text{HCHO}_d} = 4.069 \times 10^{-2}(0.39)(5.0)(0.1429)(527.67)/(1.1043)(725.42) = 0.0075 \text{ ppm.}$$

$$(xvi) \text{HCHO}_{\text{conc}} = 0.664 - 0.0075(1 - 1/24.939) = 0.6568 \text{ ppm.}$$

$$(xvii) \text{HCHO}_{\text{mass}} = (6048.1)(35.36)(0.6568/1,000,000) = 0.1405 \text{ grams per test phase.}$$

$$(xviii) \text{THCE} = 0.35 + (13.8756/32.042)(2.44) + (13.8756/30.0262)(0.1405) = 1.47 \text{ grams per test phase.}$$

$$(xix) \text{NO}_{x\text{conc}} = 5.273 - (0.146)(1 - 1/24.939) = 5.13 \text{ ppm.}$$

$$(xx) \text{NO}_{x\text{mass}} = (6048.1)(54.16)(5.13/1,000,000)(0.8951) = 1.505 \text{ grams per test phase.}$$

$$(xxi) \text{CO}_{\text{conc}} = 96.332 - 1.181(1 - 1/24.939) = 95.2 \text{ ppm.}$$

$$(xxii) \text{CO}_{\text{mass}} = (6048.1)(32.97)(95.2/1,000,000) = 18.98 \text{ grams per test phase.}$$

$$(xxiii) \text{CO}_{2\text{conc}} = 0.469 - 0.039(1 - 1/24.939) = 0.432 \text{ percent.}$$

$$(xxiv) \text{CO}_{2\text{mass}} = (6048.1)(51.85)(0.432/100) = 1353 \text{ grams.}$$

$$(xxv) \text{CH}_{4\text{conc}} = 2.825 - 2.019(1 - 1/24.939) = 0.89 \text{ ppm.}$$

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(xxvi)  $\text{NMHC}_{\text{conc}} = 3.553 \text{ ppm} - 0.89 \text{ ppm} = 2.67 \text{ ppm}$ .

(xxvii)  $\text{NMHC}_{\text{mass}} = (6048.1)(16.33)(2.67/1,000,000) = 0.263 \text{ grams per test phase}$ .

(xxviii)  $\text{NMHCE}_{\text{mass}} = 0.263 + (13.8756/32.042)(2.44) + (13.8756/30.0262)(0.1405) = 1.39 \text{ grams per test phase}$ .

(2) For the stabilized portion of the cold start test assume that similar calculations resulted in the following:

(i)  $\text{THCE} = 0.143 \text{ grams per test phase}$ .

(ii)  $\text{NO}_{\text{Xmass}} = 0.979 \text{ grams per test phase}$ .

(iii)  $\text{CO}_{\text{mass}} = 0.365 \text{ grams per test phase}$ .

(iv)  $\text{CO}_{2\text{mass}} = 1467 \text{ grams per test phase}$ .

(v)  $D_s = 3.854 \text{ miles}$ .

(vi)  $\text{NMHCE} = 0.113 \text{ grams per test phase}$ .

(3) For the “transient” portion of the hot start test assume that similar calculations resulted in the following:

(i)  $\text{THCE} = 0.488 \text{ grams as carbon equivalent per test phase}$ .

(ii)  $\text{NO}_{\text{Xmass}} = 1.505 \text{ grams per test phase}$ .

(iii)  $\text{CO}_{\text{mass}} = 3.696 \text{ grams per test phase}$ .

(iv)  $\text{CO}_{2\text{mass}} = 1179 \text{ grams per test phase}$ .

(v)  $D_{\text{ht}} = 3.577 \text{ miles}$ .

(vi)  $\text{NMHCE} = 0.426 \text{ grams per test phase}$ .

(4) Weighted emission results:

(i)  $\text{THCE}_{\text{wm}} = (0.43) \times (1.473 + 0.143)/(3.583 + 3.854) + (0.57) \times (0.488 + 0.143)/(3.577 + 3.854) = 0.142 \text{ grams as carbon equivalent per mile}$ .

(ii)  $\text{NO}_{\text{Xwm}} = (0.43) \times (1.505 + 0.979)/(3.583 + 3.854) + (0.57) \times (1.505 + 0.979)/(3.577 + 3.854) = 0.344 \text{ grams per mile}$ .

(iii)  $\text{CO}_{\text{wm}} = (0.43) \times (18.983 + 0.365)/(3.583 + 3.854) + (0.57) \times (3.696 + 0.365)/(3.577 + 3.854) = 1.43 \text{ grams per mile}$ .

(iv)  $\text{CO}_{2\text{wm}} = (0.43) \times (1353 + 1467)/(3.583 + 3.854) + (0.57) \times (1179 + 1467)/(3.577 + 3.854) = 366 \text{ grams per mile}$ .

(v)  $\text{NMHCE}_{\text{wm}} = (0.43) \times (1.386 + 0.113)/(3.583 + 3.854) + (0.57) \times (0.426 + 0.113)/(3.577 + 3.854) = 0.128 \text{ grams per mile}$ .

[56 FR 25777, June 5, 1991, as amended at 59 FR 39649, Aug. 3, 1994; 59 FR 48511, Sept. 21, 1994; 60 FR 34349, June 30, 1995; 62 FR 47122, Sept. 5, 1997; 70 FR 40434, July 13, 2005; 75 FR 22980, Apr. 30, 2010; 76 FR 57377, Sept. 15, 2011]

### § 86.145–82 Calculations; particulate emissions.

(a) The final reported test results for the mass particulate ( $M_p$ ) in grams/mile shall be computed as follows.

$$M_p = 0.43(M_{p1} + M_{p2})/(D_{ct} + D_s) + 0.57(M_{p3} + M_{p2})/(D_{ht} + D_s)$$

where:

(1)  $M_{p1}$  = Mass of particulate determined from the “transient” phase of the cold start test, in grams per test phase. (See § 86.110–82(c)(1) for determination.)

(2)  $M_{p2}$  = Mass of particulate determined from the “stabilized” phase of the cold start test, in grams per test phase. (See § 86.110–82(c)(1) for determination.)

(3)  $M_{p3}$  = Mass of particulate determined from the “transient” phase of the hot start test, in grams per test phase. (See § 86.110–82(c)(1) for determination.)

(4)  $D_{ct}$  = The measured driving distance from the “transient” phase of the cold start test, in miles.

(5)  $D_s$  = The measured driving distance from the “stabilized” phase of the cold start test, in miles.

(6)  $D_{ht}$  = The measured driving distance from the “transient” phase of the hot start test, in miles.

(b) The mass of particulate for each phase of testing is determined as follows:

$$M_{pj} = \left[ V_{\text{mix}} + V_{\text{epi}} \right] \left[ \frac{P_{\text{ei}}}{V_{\text{epi}}} - \frac{P_b}{V_{\text{bp}}} (1 - 1/\text{DF}) \right]$$

where:

(1)  $j = 1, 2$  or  $3$  depending on which phase the mass of particulate is being determined for (i.e., the “transient” phase of the cold start test, the “stabilized” phase of the cold start test, or the “transient” phase of the hot start test).

(2)  $V_{\text{mix}}$  = Total dilute exhaust volume in cubic meters per test, corrected to standard conditions 528°R (293K) and 29.92 in Hg (101.3 kPa).  $V_{\text{mix}}$  is further defined in § 86.144.

(3)  $P_e$  = mass of particulate per test on the exhaust filter(s), grams.

(4)  $P_b$  = mass of particulate on the “background” filter, grams.

(i) The background particulate level,  $P_b$ , inside the dilution air filter box at